# "THE DYNAMIC SPECIFICATION OF THE INVESTMENT FUNCTION FOR THE GREEK ECONOMY: 1954-1988"

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## 1. INTRODUCTION*

This paper is intended to examine the demand for investment goods which constitutes the second major component in total demand after the demand for consumption goods. The investment expenditure plays an important role in the economic development of any country, because the change in the future productive capacity of the economy depends on the present level of investment expenditure.

The model which is used in the next section, has the advantage that it gives us the possibility of estimating the depreciation rate of the capital stock, without having data on stocks at our disposal. Estimating the rate of depreciation of the capital stock, we then can approximate the size of the capital stock itself. Therefore, in this work besides the estimation of the investment function we proceed to the estimation of the total capital stock.

Although the multitude of factors affecting investment behaviour would seem to argue in favour of the decomposition of investment expenditure, we will concentrate on the aggregative investment activity of the economy as a whole, without considering explicitly the wide diversity of capital goods.

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In the next section we will try to present briefly the main theoretical considerations on investment in the international bibliography and also the specification of the gross private investment function which we will use in the present work. In the third section we will try to examine the data used in estimating the proposed investment function while in the fourth section we will present the estimation findings themselves, produced by applying the OLS/ALS methods. In the fifth section we estimate the capital stock (K), and the depreciation rate (δ) of the Greek economy, and in the sixth section we will discuss the empirical results in the light of the economic theory and we will compare our results with equivalent results of other similar works.

## 2. SPECIFICATION OF THE INVESTMENT FUNCTION AND GENERAL THEORY

In contrast to consumption theory, investment theory is relatively unsatisfactory. We believe that this is due to the multitude of the arguments which explain the investment behaviour and to the factor of business psychology which is difficult to quantify.

Many of the existing investment theories try to explain the behaviour of the "desired capital stock". Many authors, for example Eckaus (Eckaus R., 1953, pp. 209 – 230), Smyth (Smith D., 1964, pp. 185 – 199), Helliwell (Helliwell J., ed., 1976, p. 33, p. 63) and Lund (Lund P., 1971) have summarized these theories as follows:

### (i) The Accelerator Model

The simple (crude) accelerator model, assumes that there is a fixed relationship between the desired capital stock, $K_t^*$, and income, $Y_t$, or in other words that the desired (optimal) capital stock is proportional to the level of income, so that

$$K_t^* = aY_t \qquad (1)$$

where a is the fixed capital – income ratio (simple accelerator).

The main feature of the simple acceleration hypothesis is that the capital stock is optimally adjusted in each period, so that $K_t = K_t^*$ for all t. Thus, it is

$$I_t = K_t^* - K_{t-1}^* = K_t - K_{t-1} = a\Delta Y_t \tag{2}$$

where $\Delta Y_t = Y_t - Y_{t-1}$ and $I_t$ is net investment. However, this simple form gives very poor results.

The flexible accelerator (or partial adjustment or capital stock adjustment principle) assumes that there is the same optimal relationship between capital stock and output as in (1), but the adjustment process is not instantaneous or in other words that there are lags in the adjustment mechanism[1], so that:

$$K_t - K_{t-1} = (1-\lambda)\ (K_t^* - K_{t-1}), \quad 0<\lambda\leq 1 \tag{3}$$

where $K_t$ is the actual capital stock in time t, and $\lambda$ is a constant parameter. The above form is rewrittem as:

$$K_t = a\ (1-\lambda)\ Y_t + \lambda K_{t-1} \tag{4}$$

after substituting equation (1) in (3) and rearranging. This equation is equivalent to an expression for $K_t$ as a distributed lag function of $Y_t$ with geometrically declining coefficients, $K_t = a\ (1-\lambda)\ \Sigma_{\lambda}^{i}\ Y_{t-i}$ (Wallis, K., 1973, pp. 63–4, Wynn, R.F., and K. Holden, 1974, pp. 22–30).

Although there are disagreements in the various investment theories with respect to the factors which affect the desired capital stock and the specification of the adjustment mechanism, however, many of them are in line with reference to the specification of the depreciation function. They assume that depreciation (replacement investments) is proportional to the existing capital stock, that is:

$$D_t = \delta\ K_{t-1} \tag{5}$$

where $D_t$ is the level of depreciation in time t and $\delta$ is the rate of depreciation, or the proportion of capital stock replaced each time period. Jorgenson and Stephenson proved equation (5) in the special case of the distribution of depreciations over time being geometric so that: $D_t = \delta\ I_{t-1} + \delta\ (1-\delta)\ I_{t-2} + \ldots$ (Jorgenson, D.W., and J.A. Stephenson, 1967, pp. 178–9).

Now, gross investment is equal to net investment $(K_t - K_{t-1})$, plus depreciation:

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1. Smyth, D.J., 1964, pp. 185–199.

$$I_t = (K_t - K_{t-1}) + D_t \qquad (6)$$

or

$$K_t = K_{t-1} + I_t - D_t \qquad (7)$$

i.e. the capital stock by the end of the period equals the initial capital stock augmented by gross investment ($I_t$) less depreciation ($D_t$).

By solving the system of the equations (1), (3), (5) and (7) the following "flexible accelerator" equation for investment is obtained:

$$I_t = a\,(1-\lambda)\,Y_t - a\,(1-\lambda)\,(1-\delta)\,Y_{t-1} + \lambda\,I_{t-1} \qquad (8)$$

The advantage of the last equation is that it permits the estimation of the depreciation rate of the capital stock, indirectly, even without having data on stocks.

### (ii) The Neoclassical Investment Model

The Neoclassical theory of investment developed by Jorgenson[2] and others can be summarized as follows:

The standard Jorgenson's assumptions is that the firm is assumed to maximize the present value of future net revenues ($pY - wL - qI$) subject (i) to a technological constraint (the production function), say,

$$Y_t = A\,K_t^{a}\,L_t^{b}$$

i.e. he assumed a Cobb – Douglas production function, (ii) to the investment identity:

$$I_t = \Delta K_t + D_t$$

(iii) that the firm is assumed to produce under conditions of perfect competition, and (iv) that capital depreciates at a constant rate, where p is the price of the product, w is the wage rate of labour force (L) and q is the price of capital goods.

The actual investment expenditure at any given time (t) is a distributed lag function of current and past orders, or changes in desired (optimum) capital stock, i.e.

2. Jorgenson, D.W., 1963, pp. 249 – 59.

$$I_t^E = \sum_{j=0}^{\infty} \mu_j (K_t^* - K_{t-1}^*) \tag{9}$$

$$= \Sigma\mu_j \; Z^j \; \Delta K_t^*$$

$$= \mu (Z) \; \Delta K_t^* \tag{10}$$

where $\mu$ (Z) is a ratio of two finite polynomials in Z, Z being the lag operator, i.e.

$$\mu (Z) = \frac{J (Z)}{\gamma (Z)} = \frac{J_0 + J_1 Z + \ldots + J_k Z^n}{\gamma_0 + \gamma_1 Z + \ldots + \gamma_\theta Z^\theta} \tag{11}$$

The gross investment (total investment) $I_t$ is the sum of actual investment ($I_t^E$) and investment for replacement (depreciation), say $D_t$, so that finally is:

$$I_t = \mu (Z) \; \Delta K_t^* + D_t \tag{12}$$

where $D_t = \delta K_{t-1}$. Finally, Jorgenson's model reduces into the following investment function:

$$\gamma (Z) \{I_t - \delta K_{t-1}\} = J (Z) \Delta \left(a \frac{PY}{c}\right)_t$$

where c is the implicit rental value of capital services depending on the explicit specification of the model.

Briefly, Jorgenson's model relies on strong assumptions concerning the production function in order to obtain a simple, intuitively appealing functional form relating capital stock to its determinants. The effect of taxes, interest rates depreciation, and prices of capital goods are included in the variable $c_t$ (user cost), which enters the equation as a divisor of the value of output.

The investment functions which is used in the present paper includes the same variables as the "flexible accelerator" type (equation(8)) and in addition the interest rate, which is a link between the real and the financial sectors in the economy; i.e. they are:

$$GPI_t = \alpha_0 \, GNI_t + \alpha_1 \, GNI_{t-1} + \alpha_2 \, GPI_{t-1} + \alpha_3 r_{t-1} \tag{13}$$

and

$$TGI_t = a_0 \, GNI_t + a_1 \, GNI_{t-1} + a_2 \, GPI_{t-1} + a_3 r_{t-1} \tag{13'}$$

where GPI = Gross Private Investment at constant 1970 prices, (excluding investment of changes in inventories).

GNI = Gross National Income at constant 1970 prices.

r = Interest rate (opportunity cost for holding currency), and

TGI = Gross Private Investment including investment of changes in inventories (at constant 1970 prices).

In the above investment functions the interest rate has been introduced lagged once because we believe that the capital market in Greece is not responding immediately to changes in the interest rate.

We used the gross investment variable in the proposed investment function, instead of the net investment one, because we think that investment decisions are made with respect to total capital expenditure whether they are used for purposes of replacement or expansions.

Since the investment variable, included in the proposed investment function, represents gross capital expenditure, we shall correspondingly use the income variable representing gross national income.

Following Keynes' position[3], we are introducing the interest rate in the investment function, because the interest rate, as a cost factor, affects investment activity.

We assume that individuals (entrepreneurs) do not suffer from "money illusion" and so the investment and income variables used in the equation are expressed in real terms.

## 3. THE DATA USED

The data which were used in fitting the investment function are relevant to the gross private investment excluding investment of changes in inventories (GPI), and to the gross private investment including changes in inventories (TGI). Unfortunately, the available data for investment in ships operating overseas are not complete (there exist data until the year 1982), and so we did not use these investments in our estimates. Also, we used data with respect to gross national income (GNI) and to the interest rate (r). The interest rate is taken as the rate of discount in the Greek National Accounts which represents the rate at which

3. Klein, L.R., 1950, p. 66.

the central bank (Bank of Greece) either discounts or makes advances against eligible commercial paper and / or government securities for commercial banks.

We used Greek annual data over the time period 1954-1988. Since in the present paper we will also try to estimate the total capital stock of the Greek economy, we have also included public investment and depreciation data.

## 4. ESTIMATION OF THE INVESTMENT FUNCTION

In the present section, we will try to estimate the proposed previously investment function (equation (13)) without taking into account the changes in inventories, therefore assuming the last category of investment as being exogenous, because this is not determined by the usual economic variables. Following that, we will relax the above assumption and we will try to estimate the gross private investment function including changes in inventories (equation (13')).

Table 1 presents the results on the above mentioned investment functions using the OLS and ALS methods. Furthermore, Table 2 presents all the supplementary statistical indeces which are related with Table 1.

It can be seen in Table 1 that all the estimates of the coefficients of the variables obtained by the OLS and ALS methods are statistically significant at 5 per cent level (only the estimate of the coefficient of the lagged interest rate variable in equations 1' and 3' is insignificant at 5 per cent probability level). The coefficients of determination are very high and the F tests are significant. Moreover, the signs of the estimated coefficients of the parameters are the expected ones taking into account the economic theory on the investment function (8), and the value of D-W tests indicate that the disturbance terms in equations 1, 2, 3 and 4 in Table 1 are free of serious autocorrelation (if we overlook that the D-W tests are likely to be biased towards 2)[(4)]. However, the $\chi^2$ (i) and $\chi^2$ (1) in Table 2 indicate that the autoregressive restrictions of the first order scheme imposed on the disturbance terms in equations 1, 2, 3 and 4 in Table 1 are valid, and that the autocorrelation of the disturbance terms is insignificant respectively, while the F (j, 1) tests on the significance of the additional lagged variables show that the specifications of the investment functions of Table 1 estimated by OLS/ALS methods are correct. Therefore, rejection of the "restrictive

4. Koutsoyiannis, A., 1977, p. 309, and Gamaletsos, T., 1988, pp. 82-83.

TABLE 1

Fixed Investment Functions (OLS/ALS)

| Method | Equation | $GNI_t$ | $GNI_{t-1}$ | $GPI_{t-1}$ | $r_{t-1}$ | $TGI_{t-1}$ | $\bar{R}^2$ | D-W | F | RSS |
|---|---|---|---|---|---|---|---|---|---|---|
| OLS | 1* | 0.483008 (7.0528) | -0.426123 (-5.7456) | 0.648591 (7.3944) | -410.101971 (-1.8089) | – | 0.9951 | 2.24 | 1660.96 | 363102338.8821 |
| OLS | 2** | 0.515725 (7.5364) | -0.491181 (-7.3096) | 0.748348 (10.5902) | – | – | 0.9947 | 2.31 | 2062.36 | 402706082.5867 |
| OLS | 3*** | 0.638466 (5.2310) | -0.547213 (-3.8545) | – | -903.739693 (-2.0299) | 0.590491 (5.3143) | 0.9892 | 2.22 | 756.53 | ***** |
| OLS | 4**** | 0.751174 (6.5873) | -0.728084 (-6.2791) | – | – | 0.752676 (9.2909) | 0.9881 | 2.36 | 915.21 | ***** |
| ALS | 1′ | 0.49448 (7.3743) | -0.44456 (-6.1095) | 0.67489 (7.5687) | -343.26631 (1.4993) | – | – | – | – | ***** |
| ALS | 2′ | 0.52559 (8.0221) | -0.50276 (7.9067) | 0.75809 (11.4197) | – | – | – | – | – | ***** |
| ALS | 3′ | 0.65724 (5.4451) | -0.58565 (-4.2870) | – | -680.21462 (1.4814) | 0.64828 (5.2157) | – | – | – | ***** |
| ALS | 4′ | 0.74396 (8.6571) | -0.72423 (6.5437) | – | – | 0.77355 (9.7998) | – | – | – | ***** |

* Equation 1 is exactly the same with equation (13)

** Equation 2 is the investment function of the "flexible accelerator" type excluding investment of changes in inventories.

*** Equation 3 is exactly the same with equation (13)′.

**** Equation 4 is the investment function of the "flexible accelerator" type concerning the gross private investment activity including the changes in inventories.

(Number in parentheses are the t-ratios).

TABLE 2

Supplementary Statistical Indeces of Investment Functions

| Method | Equation | $\hat{\rho}$ | $t(\hat{\rho})$ | $\chi^2$ (i) | i | $\chi^2$ (1) | F (j, l) | j, l |
|---|---|---|---|---|---|---|---|---|
| OLS/ALS | 1/1′ | −0.16574 | 0.8064 | 3.32236 | 2 | 1.15429 | 1.21196 | 5,26 |
| OLS/ALS | 2/2′ | −0.18537 | 0.9796 | 0.62943 | 1 | 1.06277 | 0.43714 | 4,28 |
| OLS/ALS | 3/3′ | −0.17487 | 0.7499 | 3.12724 | 2 | 0.18272 | 1.86943 | 5,26 |
| OLS/ALS | 4/4′ | −0.21194 | 1.0406 | 0.48459 | 1 | 1.05988 | 0.49003 | 4,28 |

$\hat{\rho}$ = estimated autoregressive coefficient.

$x^2$ (i) = is the $x^2$ test with i degrees of freedom, on the validity of the autoregressive restrictions imposed on the disturbance terms.

$x^2$ (1) = is the $x^2$ test with 1 degree of freedom on $\hat{\rho}$ and indicates if the autocorrelation in the disturbance terms is significant.

F (j, l) = is the F test with (j, l) degrees of freedom, on the significance of the additional parameters.

transformed equations" (RTE)[5] 1′, 2′, 3′, and 4′ in Table 1 is obvious. In other words the results of Table 1 obtained by the OLS method are acceptable.

Among all these equations estimated by the OLS method we prefer equations 1 and 3 (Table 1). So these equations are rewritten:

$$GPI_t = 0.483008\ GNI_t - 0.426123\ GNI_{t-1} + 0.648591\ GPI_{t-1} - 410.101971\ r_{t-1} \quad (13)$$
$$(7.0528) \qquad (-5.7456) \qquad (7.3944) \qquad (-1.8089)$$

$$TGI_t = 0.638466\ GNI_t - 0.547213\ GNI_{t-1} + 0.590491\ TGI_{t-1} - 903.739693\ r_{t-1} \quad (13)'$$
$$(5.2310) \qquad (-3.8545) \qquad (5.3143) \qquad (-2.0299)$$

## 5. APPROXIMATION OF THE TOTAL CAPITAL STOCK

In the present section we will try to estimate the capital stock of the Greek economy which will be used to find the depreciation function.

The estimation of the depreciation rate of the total capital stock presupposes to know, except the private investment data, the public investment data, and the

5. Hendry, D.F., 1974, p. 563.

changes in inventories. (We did not take into account the investments in ships, which as it was mentioned previously, are incomplete).

From equation (7) it results that:

$$K_t - K_{t-1} = I_t - D_t \tag{14}$$

Lagging by one year the above equation we obtain:

$$K_{t-1} - K_{t-2} = I_{t-1} - D_{t-1} \tag{15}$$

from which finally results:

$$D_t - D_{t-1} = \delta\ (I_{t-1} - D_{t-1}) \tag{16}$$

(In eq. (16) $I_t$ includes the private investment data ($GPI_t$), the public investment data ($PI_t$), and the changes in stocks ($CSI_t$)).

From equation (16) we can estimate the proportional depreciation rate (δ). Estimating the depreciation rate (δ), we can approximate the capital stock using the form (5). That is:

$$\hat{K}_{t-1} = \frac{1}{\hat{\delta}} D_t \tag{17}$$

where the sign ^ over each parameter or variable means estimate of the parameter or variable respectively.

Tables 3 and 4 present the results of equation (16) using OLS/ALS methods, and the supplementary statistical tests of the depreciation function respectively.

It can be seen in equation 1 in Table 3 that the estimate of the coefficient of the $(I_{t-1} - D_{t-1})$, i.e. estimate of the depreciation coefficient $\hat{\delta}$, is statistically significant at 5% probability level. Similarly the same estimate obtained by the ALS method is significant. However, Table 4 reveals that the autocorrelation in the error terms is significant, and that equation 1′ is correctly specified. So rejection of the results obtained by the OLS method and acceptance of the results obtained by the ALS method is obvious. Therefore, the depreciation rate of the investment as a whole is $\hat{\delta}_1 = 0.021134$, which is a little smaller than that estimated by Adelman – Chenery for the Greek economy (0.0213) (Adelman, I., and H. Chenery., 1966, pp. 1 – 19), and a little bigger than that estimated by Katos (0.02018) (Katos, A., 1977, p. 66).

TABLE 3

Depreciations of the Total Economy

| Method | Dependent variable | $I_{t-1}-D_{t-1}$ | $K_{t-1}$ | Constant | $\bar{R}^2$ | D−W | F | RSS |
|---|---|---|---|---|---|---|---|---|
| OLS | 1 . $D_t - D_{t-1}$ | 0.020757 (23.2004) | – | – | 0.9439 | 1.766 | – | 21145322 |
| OLS | 2 . $D_t$ | – | 0.0224285 (144.26710) | −865.17137 (−4.8884321) | 0.9984 | 0.4033 | 20813.0 | 8091131 |
| OLS | 3 . $D_t$ | – | 0.0217649 (220.76416) | – | 0.9973 | 0.2237 | – | **** |
| ALS | 1′ . $D_t - D_{t-1}$ | 0.021134 (23.3003) | – | – | 0.9900 | 0.093 | – | 20832164 |
| ALS | 2′. $D_t$ | – | 0.0215236 (20.225171) | −283.71468 (−0.1762466) | 0.99942 | 1.74699 | – | 2714214 |
| ALS | 3′ . $D_t$ | – | 0.0217112 (101.68009) | – | 0.99943 | 1.71722 | – | 2722169 |

TABLE 4

Supplementary Statistical Indeces of the Depreciation Functions

| Method | Equation | $\hat{\rho}$ | t ($\hat{\rho}$) | $x^2$ (i) | i | $x^2$ (1) | F (j, l) | (j, l) |
|---|---|---|---|---|---|---|---|---|
| OLS/ALS | 1/1′ | 0.82398 | 10.3132 | 3.34103 | 1 | 4.46820 | 1.59589 | 2,30 |
| OLS/ALS | 2/2′ | 0.84754 | 5.86240 | 0.0002 | 1 | 21.76302 | 2.86437 | 2,30 |
| OLS/ALS | 3/3′ | 0.82396 | 10.31297 | 1.21234 | 1 | 21.92114 | 21.3564 | 2,30 |

It was said before that the estimation of $\delta$, i.e. $\hat{\delta}$, from the relation (16) permits us to proceed to the approximation of the capital stock using equation (17).

However, what is interesting in many applied works is the changes in the level of the capital stock and not the absolute level of it, thus many researchers consider quite arbitrarily one year as a basis for the accumulation of the capital stock, and then accumulate the annual increase of the net investment ($\Delta K$) with respect to this "arbitrary" level of the capital stock which corresponds to the base year.

Pavlopoulos (Pavlopoulos, P., 1966, pp. 62−4) and Adelman−Chenery (Adelman, I., and H. Chenery, 1966) followed this approach. Particularly, Adelman and Chenery took year 1950, as the base year for their approximation of the capital stock and assumed that the capital stock in the Greek economy in that year was three times higher than the gross domestic product of the same year.

We avoided this method in our work due to its arbitrariness, considering as basis for capital accumulation the period where the predicted from equation 1′ in Table 3 difference $I_{t-1}-D_{t-1}$ lies closer to the average of the corresponding difference of the actual time−series data used in this work, since the prediction error is the smallest near the average. That is, the final approximation of the capital stock is obtained by the formulae:

$$K_t=\hat{K}_T+\sum_{i=T+1}^{t} I_i-\sum_{i=T+1}^{t} D_i, \quad \text{for } t>T \tag{18}$$

and

$$K_t=\hat{K}_T-\sum_{i=t+1}^{T} I_i+\sum_{i=t+1}^{T} D_i, \quad \text{for } t<T \tag{19}$$

where $\hat{K}_t=\frac{1}{\hat{\delta}}D_t$ is the estimated capital stock in the basic time period T, which in the form (17) corresponds to the period $t-1$. The mean of the differences $(I_{t-1}-D_{t-1})$ is equal to $\cong$ 48146 and it is close to the value of year 1965. Thus, we considered this year as the basis for the capital accumulation. Then using the forms (18) and (19) we created the time−series of the capital stock over the sample period.

Table 3 presents the results of the depreciation functions using the form (5) obtained by the OLS and ALS methods, with constant term and without constant term (equations 2 and 3 respectively), while Table 4 presents the supplementary statistical tests which are related to these results. It can be observed from this Table, that equation 2 (with constant term) is not misspecified, while the autocorrelation in the error terms is significant. On the contrary, the F test in Table 4 reveals that equation 3 (without constant term) is misspecified. So, finally we accept equation) 2′ estimated by the ALS method, since the autocorrelation in the disturbance terms is significant, and the autoregressive restriction imposed on the disturbance terms is valid. Therefore, the new coefficient of depreciation which we found directly is $\hat{\delta}_2=0.02152$. This value is close to that found by Katos (0.02018), and slightly bigger than that estimated by Adelman and Chenery (0.0213). It is of cource obvious that this new rate of depreciation is close to that previously found, using the form (16). This is because the approximation of the data on the capital stock is based on this rate of depreciation.

Geronimakis (Geronimakis, S., 1964, p. 38) has estimated the depreciation rates and the average useful lifetime of capital corresponding to various sectors in Greece. Particularly, he found that the depreciation rate corresponding to buildings is 1.5%, 7% for machinery, 1% for other equipment, and 5% for all the other capital goods. The average depreciation rate for the manufacturing sector has been estimated by him to be around 5.6-5.9%.

The above percentage implies that the useful lifetime of all capital assets in Greek manufacturing is near to 16-18 years. On the other hand, Krengel and Mertens (Krengel, R., and D. Mertens, 1966, p. 32) suggested that the depreciation rates estimated by Geronimakis are lower than those found in other international works. They also suggested that the useful life-time of assets is from 25 to 30 years corresponding to a depreciation rate equal to 3.6% while in i.e. United States is 27 to 28 years, USSR is 30 to 31 years and the Federal Republic of Germany is 29 to 30 years.

## 6. ANALYSIS AND COMPARISON OF THE ESTIMATES

Although both equations (13), (13)' were accepted for further analysis, in fact we proceeded with equation (13) since it enjoys a better fit ($R^2$ and F). This perhaps is due to the absence of investment in ships from equation (13)' and the inclusion of stocks which exhibit exceptional variability.

In the present section we will try to analyse the results of the investment function (13) estimated in this work, and we will also compare these results with those obtained by other investment forms (estimated also in this work) and with the results of other researchers.

It may be observed in equation (13) the great importance of the demand factors (income variables). The short-term marginal propensity to invest with respect to current income is 0.48300. The marginal effect of the previous income on the present investment is $-0.42612$. The negative sign is also consistent with the investment theory under the "flexible accelerator hypothesis". Substituting equation (5) in equation (7) and solving with respect to the investment variable, it results that investment depends negatively on the level of the previous capital stock ($K_{t-1}$)[6].

6. Statistical investigations reveal a very strong negative correlation between investments and the stock of capital. (Klein, L.R., 1950, pp. 68-9).

However, between capital stock and income there is positive relationship (equation (1)), and therefore due to the above negative relation the present level of investment depends negatively on the previous level of income.

The influence of previous investment activity on current investment expenditure is 0.64859 (i.e. adjustment coefficient is 0.35141). The significance of the lagged investment variable is evidence that there is some "hysteresis" in the reaction of the entrepreneurs and also that there is a technical lag (delivery lag) between the ordering and purchase of capital goods. It has been found that the appropriate lag is a time unit of one year, since the producers make their decisions usually on the basis of the results presented in statements and accounts normally prepared each year. So the introduction of the lagged investment variable in the presented private investment function captures the so called "echo effects".

Apart from the importance of the demand factors, the financial factors, i.e. interest rate, also affect the investment decisions of the entrepreneurs. The marginal effect of the interest rate on the investment expenditure is -410.1019. The interest rate taken as the opportunity cost, affects negatively the investment activity. This finding reveals that in the Greek economy the financing of capital goods depends also on the money market; that is the monetary sector influences the real sector. The entrepreneurs take into account the interest rate changes when making investment decisions. In fact, self-financing through undistributed profits and other reserves, particularly in manufacturing sectors, has recently been declining and the corresponding external finance has come from borrowing from the banks[7].

Table 5 shows the short - run and long - run marginal propensities to invest with respect to the various explanatory variables, the marginal effects of past investment on present investment activity estimated by the OLS method, and the corresponding elasticities in each case. The demand for investment goods is (in absolute terms) elastic with respect to income (present and previous income) and is inelastic with respect to previous investment and interest rates.

The importance of gross income as explanatory variable in the investment function supports the profits hypothesis, if we take into account that the income could be considered as a proxy of profits.

The estimates of the coefficients of the variables which we found are close to those found by Katos (Katos, A., 1977).

7. Ellis, H.S. et al., 1964, pp. 314-5.

Zonzilos and Brissimis (Zonzilos, N., and S. Brissimis, 1978, pp. 95 – 115) using, in their econometric model for the Greek economy, an investment function similar to that which we proposed in the present work, found that the marginal effect of the current interest rate on the gross private investment is $-0.493$, while we found that the lagged once interest rate exerts weaker effect on the gross private investment, i.e. $-0.410$. Moreover, they found that the influence of the past investment expenditure is relatively strong, i.e. 0.7684, while we found that the corresponding influence is 0.64859. The above authors, besides the variables which we also used in our proposed investment function, introduced a constant term which, it is reasonable to accept, will alter some effects in the other variables. Furthermore, they imposed a restriction on the coefficients of the current national income and of the previous national income, assuming these variables exert the same effect in absolute terms on the gross private investment, i.e. 0.4093 (2SLS), while we found that the influences of the current income and previous income on the gross private investment are $\cong 0.4830$ and $\cong -0.42612$ respectively.

Tsoris (Tsoris, N., 1976, pp. 116 – 119) in his model, also estimated private investment functions excluding ships, as we did. His "best" investment equation included as explanatory variables the annual change in the GDP in real terms, the total long – run credit flow at constant 1958 prices, and the capital inflows for business lagged one year. In contrast to our results, he found that the income variable was statistically insignificant, while the sign of the coefficient of the lagged capital stock was wrong. He also did not find the interest rate to be a significant factor in his private investment function.

Pavlopoulos (Pavlopoulos, P., 1966) decomposed the total private investment into two components: plant and equipment ($I_p^0$) and residential construction ($I_p^H$). He found that the previous gross national income ($GNI_{-1}$) significantly affected the investment decisions in plant and equipment. Particularly, he found that the partial elasticity of $I_p^0$ with respect to $GNI_{-1}$ was about 2.42 (close to mine for the overall effect), but the sign of the coefficient of the last variable was positive, while we found (and we believe correctly) that the sign of the coefficient of the lagged income variable is negative.

Pavlopoulos did not consider the interest rate as an explanatory variable in his investment function.

In view of international findings concerning the investment functions, we would like to mention that in many econometric studies the interest rate is largely neglected. Particularly, Tinbergen (Tinbergen, J., 1942, p. 170) found that the rate interest is an insignificant variable in the investment equation of his statistical

TABLE 5

Marginal propensities to invest with respect to current income, previous investment, previous interest

| Method | Equation | m.p.i. with respect to current income | | m.p.i. with respect to previous income | | m.p.i. with respect to previous invest. | m.p.i. with respect to previous interest rate | |
|---|---|---|---|---|---|---|---|---|
| | | Short-run | Long-run | Short-run | Long-run | | Short-run | Long-run |
| OLS | 13 | 0.483008 | 1.37448 | −0.42612 | −1.21261 | 0.64859 | −410.1019 | −1167.0218 |
| OLS | 13′ | 0.63846 | 1.55910 | −0.54721 | −1.33626 | 0.59049 | −903.7396 | −2206.886 |
| OLS | 2* | 0.51572 | 2.04935 | −0.49118 | −1.95182 | 0.74834 | – | – |
| OLS | 4** | 0.75117 | 3.03720 | −0.72808 | −2.94384 | 0.75267 | – | – |

* Equation 2 is exactly the same with equation 2 in Table 1.

** Equation 4 is exactly the same with equation 4 in Table 1.

rate and elasticities with respect to incomes, previous investment, and interest rate

| Elasticity with respect to income | | Elasticity with respect to previous income | | Elasticity with resp. to previous investment | Elasticity with respect to interest rate | |
|---|---|---|---|---|---|---|
| Short–run | Long–run | Short–run | Long–run | | Short–run | Long–run |
| 3.12482 | 8.89220 | −2.65241 | −7.54796 | 0.62828 | −0.10566 | −0.30068 |
| 3.58300 | 8.74959 | −2.95465 | −7.21511 | 0.57946 | −0.20198 | −0.49323 |
| 3.33645 | 13.25827 | −3.05738 | −12.14922 | 0.72491 | – | – |
| 4.21553 | 17.04462 | −3.93125 | −15.89521 | 0.62388 | – | – |

model. Klein and Goldberger (Klein, L., and A. Goldberger, 1969, pp. 10-12) although recognises the importance of interest changes in investment decisions, they have not been able to make a reasonable judgement about its effect and cannot assign it a reliable non - zero value in this relation. Moreover, De Leeuw (De Leeuw, F., 1962, p. 422) supports that "the association of interest rates and capital spending by manufacturers is not so common a finding of recent studies".

On the contraty Klein and Shinkai (Klein, L., and Y. Shinkai, 1963, pp. 11-12) found, for the Japanese economy, that the interest rate has a significant effect on investment behaviour. Particularly, they found that the marginal effect of interest rate on net investment expenditure was equal to - 0.678 which is bigger than that we found for the Greek economy (in same units is -0.410).

It was said before that we also estimated some other forms of investment functions. More specifically, we estimated the investment function based on the "proper" partial adjustment model, (8), excluding investment in ships and also excluding changes in inventories.

Table 1 presents the numerical estimates of the coefficients of the variables included in equation (8). Furthermore, in the same Table we present the results obtained by estimating equation (8) with different data.

As one can see from Table 1 the marginal effects of the included variables in equation (2) are higher than those found in equation (1), since the last form of the investment equation also includes the interest rate as an explanatory variable of the investment activity, and then, as it was said before, this variable absorbs some of the effects of the other variables in equation (1). As a consequence the values of the estimated elasticities of investment with respect to the various explanatory variables are higher in the case of equation (2), than those estimated by the proposed investment equation (equation (1)). These values are presented in Table 5.

As it was said previously, the advantage of the "flexible accelerator" equation for investment (8) is that it is possible from that to estimate the depreciation rate of the capital stock ($\hat{\delta}$) without having data on stocks. In fact the estimation of the depreciation rate ($\hat{\delta}$) results from the solution of the following system of equations (20):

$$\begin{aligned} \hat{a}\,(1-\hat{\lambda}) &= \hat{b}_1 \\ -\hat{a}\,(1-\hat{\lambda})\,(1-\hat{\delta}) &= \hat{b}_2 \qquad (20) \\ \hat{\lambda} &= \hat{b}_3 \end{aligned}$$

where $\hat{b}_1$, $\hat{b}_2$ and $\hat{b}_3$ are the estimates of the coefficients of the variables $GNI_t$, $GNI_{t-1}$ and $GPI_{t-1}$ respectively in equation (2) in table 1, that is 0.515725, −0.491181 and 0.748348 respectively. The value of the depreciation rate which results solving the above system of equations is equal to $\hat{\delta}_3 = 0.04759$ which, as one can see, is higher than that found previously applying the form (5) for the economy as a whole, i.e. = 0.02152.

Furthermore, we estimated the investment function similar to the "flexible accelerator" type (equation (8)) including in the private investment expenditure, the changes in stocks (equation (4) in Table 1). The results of this equation are also presented in Tables 1 and 5.

The estimate of the depreciation rate which results from equation (4) (in Table 1), following the same procedure as before, with $\hat{b}_1$, $\hat{b}_2$ and $\hat{b}_3$, to be equal to the estimates of the coefficients of the variables in this equation, i.e. 0.751174, −0.728084, and 0.752676 respectively, is equal to $\hat{\delta}_4 = 0.03073$, which is higher than that corresponding to the total economy as a whole which we found previously, i.e. $\hat{\delta}_2 = 0.02152$, and is smaller than the result from equation (2) in Table 1, i.e. $\hat{\delta}_3 = 0.04759$.

## 7. CONCLUSIONS

The main conclusions of this paper are:

1. The estimated private investment function gave satisfactory results. The explanatory variables included in this equation, that is the income variables as well as the interest rate significantly affected the private investment decisions.

2. The elasticities (short-run and long-run) of the investment with respect to the income variables appeared quite high, which means that the investment decisions were affected seriously by the income changes.

3. The importance of the interest rate variable, revealed (contrary to the results of earlier similar works)[8] that the financing of the capital goods in the Greek economy depends also on the bank lending system. Therefore, the credit and monetary policies which are designed to infulence the level of the interest rate play important role when investment decisions are made.

4. In spite the fact, that the reduced form equation of the so - called "partial

8. Except the results, which have been found by Zonzilos and Brissimis; Zonzilos, N., and S. Brissimis, 1978, pp. 95-115.

adjustment hypothesis" (equations (2) and (4) in Table 1) gave satisfactory results in view of economic and statistical criteria, it appears to be inferior compared with the same equations which include the interest rate as a further explanatory variable.

5. The annual depreciation rate for the total economy, which we found to be approximately equal to 2%, is similar to that estimated by other authors.

6. The reduced form equations which we estimated, taking into account the changes in inventories in the private investment activity, revealed that the interest rate was significant.

## APPENDIX A

Gross Private Investment, Changes in Stocks and Depreciation
(In Million drs., and at constant 1970 prices)

| YEAR | INDEX | GPI | TGI | CSI | DEPREC |
|---|---|---|---|---|---|
| 1954 | 1 | 10378 | 5993 | −4385 | 5417 |
| 1955 | 2 | 11609 | 5957 | −5652 | 5609 |
| 1956 | 3 | 13854 | 8268 | −5586 | 5911 |
| 1957 | 4 | 13643 | 10341 | −3302 | 6209 |
| 1958 | 5 | 17469 | 18094 | 625 | 6695 |
| 1959 | 6 | 16962 | 15609 | −1353 | 7073 |
| 1960 | 7 | 19264 | 18699 | −565 | 7527 |
| 1961 | 8 | 19703 | 22095 | 2392 | 7947 |
| 1962 | 9 | 22216 | 22267 | 51 | 8515 |
| 1963 | 10 | 24557 | 28413 | 3856 | 9185 |
| 1964 | 11 | 30826 | 35030 | 4204 | 10014 |
| 1965 | 12 | 35072 | 42451 | 7379 | 10940 |
| 1966 | 13 | 36610 | 38450 | 1840 | 11905 |
| 1967 | 14 | 34315 | 38975 | 4660 | 12920 |
| 1968 | 15 | 43863 | 45299 | 1436 | 13998 |
| 1969 | 16 | 51091 | 54975 | 3884 | 15429 |
| 1970 | 17 | 50737 | 63497 | 12760 | 16860 |
| 1971 | 18 | 55112 | 64802 | 9690 | 18440 |
| 1972 | 19 | 64122 | 70204 | 6082 | 20200 |
| 1973 | 20 | 72187 | 97974 | 25787 | 22378 |
| 1974 | 21 | 52211 | 72109 | 19898 | 23889 |
| 1975 | 22 | 53702 | 64078 | 10376 | 25195 |
| 1976 | 23 | 58717 | 68938 | 10221 | 26720 |
| 1977 | 24 | 67400 | 82548 | 15148 | 28350 |
| 1978 | 25 | 70430 | 86380 | 15950 | 29800 |

| | | | | | |
|---|---|---|---|---|---|
| 1979 | 26 | 76385 | 93472 | 17087 | 31994 |
| 1980 | 27 | 70465 | 97099 | 16634 | 33761 |
| 1981 | 28 | 63495 | 69165 | 5670 | 35102 |
| 1982 | 29 | 60300 | 64688 | 4388 | 36753 |
| 1983 | 30 | 56000 | 64164 | 8164 | 37896 |
| 1984 | 31 | 48570 | 59210 | 10640 | 38794 |
| 1985 | 32 | 49670 | 60966 | 11296 | 39850 |
| 1986 | 33 | 50510 | 56685 | 6175 | 40495 |
| 1987 | 34 | 52256 | 54840 | 2584 | 40862 |
| 1988 | 35 | 58100 | 64137 | 6037 | 41460 |

Source: Ministry of Coordination: National Accounts of Greece, N° 22, 23, 24, Provisional National Accounts of Greece, 1980.
National Statistical Service of Greece, 1987.
International Monetary Funds, Washington, U.S.A.
The Greek Economy, Bank of Greece, Athens 1982. Monthly Statistical Bulletin, Bank of Greece, 1978, 1984, 1987.

GPI = Gross Private Investment
CSI = Changes in inventories
DEPREC = Depreciation
TGI = GPI + CSI

## APPENDIX B

### Public Investment, Gross National Income, and Capital Stock (In Million drs., and at Constant 1970 prices), and Interest Rate (Per cent, per annum)

| YEAR | INDEX | PI | GNI | r | $\hat{K}$ (estimated) |
|---|---|---|---|---|---|
| 1954 | 1 | 2996 | 95000 | 10 | 323288 |
| 1955 | 2 | 4183 | 101478 | 9 | 327819 |
| 1956 | 3 | 5941 | 110751 | 10 | 336117 |
| 1957 | 4 | 6573 | 117837 | 10 | 346822 |
| 1958 | 5 | 7412 | 121995 | 11 | 365633 |
| 1959 | 6 | 8010 | 126897 | 9 | 382179 |
| 1960 | 7 | 9608 | 131272 | 6 | 402959 |
| 1961 | 8 | 12453 | 146200 | 6 | 429560 |
| 1962 | 9 | 12630 | 147468 | 6 | 455942 |
| 1963 | 10 | 10937 | 162485 | 5.5 | 486107 |
| 1964 | 11 | 15518 | 174825 | 5.5 | 526641 |
| 1965 | 12 | 15389 | 190871 | 5.5 | 572541 |
| 1966 | 13 | 14732 | 201118 | 5.5 | 614818 |
| 1967 | 14 | 15367 | 210760 | 4.5 | 656240 |

| | | | | | |
|---|---|---|---|---|---|
| 1968 | 15 | 14855 | 223172 | 5 | 702396 |
| 1969 | 16 | 20420 | 243478 | 6.5 | 762362 |
| 1970 | 17 | 20512 | 263503 | 6.5 | 829511 |
| 1971 | 18 | 24471 | 286076 | 6.5 | 900344 |
| 1972 | 19 | 29260 | 312228 | 6.5 | 979608 |
| 1973 | 20 | 28629 | 339025 | 9 | 1083833 |
| 1974 | 21 | 24941 | 332085 | 8 | 1156994 |
| 1975 | 22 | 31682 | 347471 | 10 | 1227559 |
| 1976 | 23 | 30212 | 367520 | 10 | 1299989 |
| 1977 | 24 | 20352 | 381125 | 11 | 1374539 |
| 1978 | 25 | 20720 | 402250 | 14 | 1451839 |
| 1979 | 26 | 22736 | 420200 | 15.92 | 1536053 |
| 1980 | 27 | 22240 | 429108 | 19.75 | 1621631 |
| 1981 | 28 | 22255 | 428759 | 20.5 | 1681080 |
| 1982 | 29 | 23800 | 428879 | 20.5 | 1704896 |
| 1983 | 30 | 27000 | 426098 | 20.5 | 1755232 |
| 1984 | 31 | 29730 | 434881 | 20.5 | 1808054 |
| 1985 | 32 | 32690 | 445631 | 20.5 | 1859636 |
| 1986 | 33 | 26709 | 445860 | 20.5 | 1907251 |
| 1987 | 34 | 18908 | 446577 | 20.5 | 1929875 |
| 1988 | 35 | 19477 | 467109 | 19 | 1962383 |

Source: Ministry of Coordination: National Accounts of Greece, N° 22, 23, 24, Provisional National Accounts of Greece, 1980.
National Statistical Service of Greece, 1987.
International Monetary Funds, Washington, U.S.A.
The Greek Economy, Bank of Greece, Athens 1982.
Monthly Statistical Bulletin, Bank of Greece, 1978, 1984, 1987.

PI = Public Investment
GNI = Gross National Income
$\hat{K}$ = Capital Stock (estimated)
r = Interest Rate.

## APPENDIX C

### Autocorrelation and Specification in Single Dynamic Equation

Here we will present, briefly, the econometric techniques, which were used in order to estimate the equation of the present paper.

It is known that the appearance of lagged endogenous variables and autocorrelated disturbances in many equations induces serious statistical problems. As consequence of autocorrelation due to misspecification of the behaviour of the error term the estimates of the coefficients are not best (they do not possess the minimum variance).

The determination of an appropriate dynamic specification in a single equation is an empirical matter resolved by experimenting using lagged endogenous variables. Assume that we want to estimate the following equation:

$$y_t = b_0 + b_1 y_{t-1} + b_2 x_t + u_t, \qquad t = 1, 2, \ldots, T \tag{A.1}$$

where $y_t$ is an observation of the endogenous variable in year t, $x_t$ is an observation of the exogenous variable also in year t, and $u_t$ is the disturbance term which is liable to a first-order scheme of autocorrelation:

$$u_t = \rho u_{t-1} + \varepsilon_t, \qquad t = 1, 2, \ldots, T \tag{A.2}$$

where $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ and $cov(\varepsilon_i, \varepsilon_j) = E(\varepsilon_i \varepsilon_j) = 0, \quad i \neq j$

Assuming that the random variable $u_t$ is serrially correlated with a first order autoregressive scheme, and as consequence an important assumption of the linear regression model is violated, the OLS methods yields both biased and inconsistent estimates.

In this case, two methods have been proposed for the estimation of the model (A.1); the instrumental variables method (IV), and the Generalised Least Squares Method (GLS). The IV method yields consistent but asymptotically inefficient estimates. So, the application of the GLS method to equation (A.1), which is equivalent to the application of the OLS method to the transformed equation (A.3), is more appropriate:

$$y_t = b_0(1-\rho) + (b_1+\rho)\, y_{t-1} - (\rho b_1)\, y_{t-2} + b_2\, x_t - (\rho b_2)\, x_{t-1} + \varepsilon_t \tag{A.3}$$

where ρ is the autoregressive coefficient, which is usually unknown. So, the estimation of the b's, and ρ applying the OLS method will produce problems, since equation (A.3) is non-linear in the parameters. Since there are non-linear restrictions in the parameters of equation (A.3), this is known as the "restricted transformed equation" (RTE).

On the other hand, it is likely that the source of autocorrelation of the error term u will be due to the omission of some important variables (mis-specification of equation (A.1)), (this case of autocorrelation is known as "quasi-autocorrelation" since it is due to the autocorrelated pattern of omitted explanatory variables, and not to the behavioural pattern of the values of the true u, (Koutsoyiannis, A., 1977, pp. 203-5)) and hence the correct form is:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + a_3 x_t + a_4 x_{t-1} + \upsilon_t \quad (A.4)$$

In contrast to equation (A.3), the parameters of (A.4) are not subjected to non-linear restrictions and thus it is denoted as the "unrestricted transformed equation" (UTE).

The sources of autocorrelation are mis-specification of the behaviour of u and omission of important variables (these are the more common sources of autocorrelation). So, if autocorrelation due to mis-specification of the error term is present, equation (A.3) is estimated by a method which is known as the method of "autocorrelated least squares" (ALS).

In the case where autocorrelation is present due to mis-specification of the equation, then equation (A.4) is selected as a new baseline for new specifications, applying OLS methods, until a better specified equation is obtained in which the source of autocorrelation (if it exists) is the mis-specification of the error structure, since in this case it is possible to estimate the new specified equation. In order to test the existence or not of autocorrelation in the disturbance term the following $x^2$ test is used (Hendry, D.F., 1974):

$$T\log (S_1/S_3) \underset{A}{\sim} x^2 (1) \quad \text{on } H_0: \rho = 0 \text{ and } H_a: \rho \neq 0 \quad (A.5)$$

where $S_1$ is the residual sum of squares (RSS) obtained by application of OLS method in equation (A.1), $S_3$ is the (RSS) which result by the application of ALS method in RTE (equation (A.3)), T is the number of used observations, and A is a symbol denoting that relation (A.5) is an "asymptotic" one.

If the above $x^2$ test reveals that autocorrelation in the disturbance term is serious, then the source of this autocorrelation is determined by using the following $x^2$ test:

$$T\log (S_3/S_2) \underset{A}{\sim} x^2 (i) \quad \text{on } H_0\text{: valid autoregressive restrictions} \quad (A.6)$$

imposed on the residuals in equation (A.3), and $H_a$: Invalid restrictions.
$S_2$ is the RSS obtained by the application of OLS in (A.4), and i is the number of restrictions imposed on (A.4) to obtain (A.3), that is the number of variables in equation (A.3) minus the number of parameters to be estimated.

If no test is significant one chooses an equation (A.1) with white noise errors (Hendry, D., op. cit). Moreover, it is likely to face the case where equation (A.1) is mis-specified, while the disturbance term $u_t$ is normal. In order to test this possibility one can construct either the F(j, l) test for the additional explanatory variables in UTE (where j is the number of parameters of the restricted equation (A.3), and l is equal to the difference between the number of observations and the number of unrestricted parameters), or individually by the t tests for the additional explanatory variables.

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